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INTERACTIONS MEASUREMENT PAYLOAD FOR SHUTTLE

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The purpose of the Interactions Measurement Payload for Shuttle (IMPS) is to develop a payload of engineering experiments to determine the effects of the space environment on projected Air Force space systems. Measurements by IMPS on a late-1980s polar-orbit Shuttle flight will lead to detailed knowledge of the interaction of the low-altitude polar-auroral environment on materials, equipment and technologies to be used in future large, high-power space systems. The results from the IMPS measurements will provide direct input to MIL-STD design guidelines and test standards that properly account for space-environment effects.

INTRODUCTION

The adverse effects of the space environment on space systems have caused many operating anomalies in communication and surveillance satellites. These anomalies were mainly associated with energetic-particle radiation or with spacecraft charging at geosynchronous altitudes. For larger space systems operating in low-earth polar orbits, a new set of environment-induced interactions will affect the operation of various equipments and subsystems. These adverse effects may limit the construction or mechanical performance of large structures in space or limit the power levels available for solar-cell sources. Before any new Air Force space systems are built and deployed, we must obtain sufficient environment-interaction information to assure their continued effective operation in space.

The effects of the space environment on large-structure, high-power space systems are unknown. Of particular concern is operation in the polar-auroral region at low to medium altitudes (200 to 2000 km). The physical processes of this regime and the interactions of the environment with materials, subsystems, and technologies characteristic of Air Force space systems of the 1990s must be quantified to assure the reliable operation of projected space systems. IMPS will measure polar-auroral effects on solar-array panels, spacecraft materials, structures, electronic subsystems, and astronaut EVA equipment. It emphasizes application to large, high-power systems and is directed toward technologies identified in the Military Space Systems Technology Model (MSSTM).

SPACE OPERATIONS AND POSSIBLE INTERACTIONS

The first step in deciding what instrumentation should be included in IMPS is to define several Air Force space-operations objectives and determine how the space environment will interact with the equipment or technologies needed to carry out those operations. Since IMPS will fly in polar orbit, polar-auroral environment interactions will be emphasized. The purpose of the IMPS measurements will be to quantify important environmental interactions -- those that will restrict certain kinds of space operation, limit the performance of a particular system, or prevent (or make impractical) the use of a certain technology. After deciding what kinds of interaction are likely to have serious effects, we must determine what interaction parameters can actually be measured on a polar-orbiting Shuttle flight. In conjunction with the measurements of effects on materials, equipments and technologies, we must characterize the physical properties of the environment causing the interactions. The determination of the required interactions measurements will lead to a definition of IMPS mission objectives.

Some generic Air Force space operations to be addressed by IMPS are:

a. Operation of optical systems

b. Operation of radar systems

c. System deployment or on-orbit repair necessitating astronaut extra-vehicular activity (EVA).

Operation in the polar-auroral environment is to be stressed.

Possible space-environment effects on optical systems include:

(1) Effects associated with large heat dissipation resulting from the low efficiency of lasers or cryogenic refrigerators (for cooled infrared detectors).

(2) Effects of contamination and material property changes on optical surfaces.

(3) Limitations in power generation due to leakage or arc-discharge in solar arrays.

(4) Plasma effects on solar-cell material.

(5) Differential charging of closely-packed small dielectric surfaces (multi-element infrared detectors).

(6) Effects on large high-precision structures used to support and point complex optical assemblies.

Figure 1 shows a possible configuration for a space-based radar system, from which one can begin to perceive potential environmental interactions. Some possible space-environment effects on radar systems include:

(1) Limitations in power generation due to leakage or arc-discharge in solar arrays.

(2) Plasma effects on solar-cell material.

(3) For power distribution utilizing high voltages: arc-discharges, dielectric breakdowns.

(4) For power distribution utilizing high currents: structural stresses and torques due to large prime-power current loops and in-orbit varying terrestrial magnetic field.

(5) Electromagnetic interference (EMI) affecting radar receiver performance.

(6) Plasma effects (such as differential charging) on feed structure and reflector materials.

Figure 2 shows astronauts engaged in space-system deployment or in-orbit repair activities requiring EVA. Some possible space-environment effects on this activity include:

(1) Differential charging between the astronaut and his spacecraft or the spacecraft being repaired due to particular environmental conditions in the area.

(2) Interactive effects on the electronics of future EVA-systems due to electromagnetic interference or differential charging.

(3) Effects in the space-plasma environment due to thermal-control water discharge in the astronaut's Life Support System (LSS).

IMPS CONCEPTS

The objective of the Interactions Measurement Payload for Shuttle (IMPS) program is to develop a payload of appropriate engineering experiments to measure the effects of the polar-auroral environment on materials, subsystems, and technologies that will be used in future Air Force space systems. The payload will consist of:

a. A complement of engineering experiments to measure and quantify the different kinds of interactive effects caused by the environment on various parts of projected future space systems.

b. In support of the engineering experiments, a limited set of polar-auroral environment sensors to characterize the environment causing the disruptive interactive effects.

Interactive effects to be investigated by the engineering experiments will include:

(1) Interaction of the auroral plasma and current sheets on high-voltage solar arrays, resulting in power leakage or arc-breakdown.

(2) Interaction of spacecraft electrical currents with polar magnetic fields on large space structures, causing torques or structure deformation (reducing the pointing accuracy of a large antenna, for example).

(3) Interactions that increase electromagnetic interference, reducing the effectiveness of space communications or surveillance systems.

(4) Interactions that degrade the properties or performance of materials or electronic circuitry, resulting in operational anomalies or subsystem failures.

(5) Interactions that pose a threat to the astronaut during polar-orbit EVA (causing a malfunction in the astronaut's Manned Maneuvering Unit, for example).

Figure 3 illustrates the concept of the Interactions Measurement Payload being developed under Project 2822. The IMPS effort is one of three projects in Program Element 63410F, Space Systems Environmental Interactions Technology. PE 63410F is an integral part of the Agreement for NASA/OAST - USAF/AFSC Space Interdependency on Spacecraft-Environment Interaction (May 1980). Under PE 63410F, IMPS is responsible for polar-auroral interactions measurements. IMPS will make substantial use of the space techn logies and instrumentation developed by NASA technology centers and Air Force organizations such as Air Force Wright Aeronautical Laboratories (AFWAL).

IMPS PRELIMINARY WORK

Initial Payload Concept Study

In FY82, Jet Propulsion Laboratory (JPL), under the direction of Air Force Geophysics Laboratory (AFGL), carried out a basic shuttle payload concept study. It was through this study that many of the basic concepts for IMPS were first defined. In December 1981, JPL hosted a meeting attended by about 70 experts in a number of key spacecraft interaction areas. Experiment questionnaires were distributed to the meeting's participants; ultimately about 70 were returned. The information from these questionnaires was used by JPL to put together an initial IMPS experiments list which was subsequently reviewed and modified by AFGL. Additional reviews and meetings with AFGL, JPL, and AF Space Division personnel lead to further refinements in the payload concept. Eventually, three sequential payloads were defined, each of the latter payloads adding to the experiments of the previous one.

Payload A consisted of engineering experiments and environmental sensors, but had no "active" engineering experiments (experiments that contribute to the environment causing the interactions). Payload B had, in addition to A's experiments and sensors, two "active" engineering experiments: a Charge Control System (CCS) and a Plasma Interactions Experiment (PIX). Payload C added (to Payload B) an experiment evaluating interactions with astronaut EVA systems. Payload C is shown in Figure 4. AFGL has submitted a Space Flight Request (DD Form 1721) for IMPS utilizing JPL's Payload C to the Space Test Program (STP). IMPS (AFGL-306) now ranks high on the priority list for Shuttle flight under STP.

IMPS Baseline Definition

Before beginning the full-scale development of instrumentation for IMPS, one must first develop a program baseline. For this purpose, Jet Propulsion Laboratory, under AFGL's direction, recently began an IMPS baseline definition effort to include:

a. Determination of what will be required of the IMPS mission to satisfy Air Force space-operations objectives.

b. Preliminary and final recommendations for selection (by AFGL) of engineering experiments and environmental sensors for IMPS through the work of an Engineering/Science Working Group (ESWG).

c. A recommended IMPS implementation plan to serve as a guide for the large-scale future work to develop, test, integrate, and fly IMPS.

d. A cost estimate for the IMPS program (for later trade-off studies).

IMPS FOLLOW-ON WORK

In general, the engineering experiments for IMPS will be obtained through the AF laboratories, NASA technology centers, and other science and engineering organizations that will be developing hardware and technology for future space application. Because these organizations are looking forward to the successful usage or operation of their hardware/technology in space, they have shown a strong interest in the IMPS program as a means of finding out how their hardware/technology will be affected by the space environment. AFGL will provide to these organizations support from the IMPS program to put together engineering experiments involving their internally-developed materials, equipment, or technologies. These experiments will be designed, fabricated, and tested under the direction of the of the particular AF laboratory, NASA technology center, or other S&E organization. In most instances, the detailed work will be carried out through contracts with universities, research organizations, and industrial companies.

Experiment and Sensor Development

Work on IMPS instrument development will include:

a. Selection of required engineering experiments and environmental sensors by AFGL.

b. Design of the individual engineering experiments.

c. Development and fabrication of the experiments and sensors.

d. Testing of individual engineering experiments and environmental sensor packages at the builder's facility to ensure that they fulfill IMPS requirements for making the various measurements. Testing to ensure that they conform to IMPS guidelines regarding command and power distribution, recording and telemetry, etc. Testing to ensure the experiments and sensors meet Shuttle operations and safety standards.

Integration and Shuttle Flight

AFGL will bring together the engineering experiments and environment sensors obtained from the various organizations responsible for their development and deliver them to the Space Test Program for integration. STP will then become responsible for IMPS. Shuttle flight arrangements and scheduling will also be handled by STP.

Data Analysis

During the Shuttle flight of IMPS, there will be a need for real-time monitoring of some of the instruments. Although IMPS operation will be made essentially automatic, careful monitoring will be required when an "active" part of an experiment (a plasma source, for example) is turned on. It is also important that during a significant event (an encounter with an auroral arc, for example) the data collection rate be increased, so as to permit later high-time-resolution analysis of important phenomena.

After the flight of IMPS aboard Shuttle, the Space Test Program will provide AFGL with data for the various engineering experiments and environmental sensors. Additionally, STP will provide orientation and geographic position of the Shuttle, position and orientation of any packages moved out of the bay, information on thruster firings, "housekeeping" data, etc. Under a data utilization plan developed before the Shuttle flight, AFGL will distribute the data for analysis. The data will go not only to those responsible for the individual experiments but also to organizations selected to do comprehensive analyses on various interaction phenomena. Particular attention will be paid to correlating changes in the physical properties of the environment with enhanced interactions noted on particular materials or equipment.

Within the first year following a successful IMPS Shuttle flight, AFGL will conduct a series of data workshops at which the IMPS data would be made available so that experimenters can compare their results. Workshops would be confined to key topics such as contamination & materials degradation, or charging & arc-discharges, or EMI generation, etc. By keying on a particular topic, it should be possible to generate an authoritative report on that subject as the output of the workshop. These reports can then be directed toward improving relevant MIL-STD design guidelines and test standards by providing the proper environmental interaction input.

CONCLUSIONS

The successful operation of the Interactions Measurement Payload on a late-1980s Shuttle flight will lead to detailed knowledge of the effects of the polar-auroral environment on materials, equipment and technologies of future space systems. The output from IMPS will provide direct input to the development of MIL-STD design guidelines and test standards for planned military space systems. The data collected by IMPS can be used to validate computer-aided design (CAD) tools that properly account for space-environment effects. The utilization of the information gathered from the IMPS measurements will prevent operational failures due to unanticipated environmental effects and minimize costly down-stream redesign of expensive space systems. Risks to spacecraft and crews will be greatly decreased by the elimination of uncertainties about the disruptive effects of the polar-auroral environment.

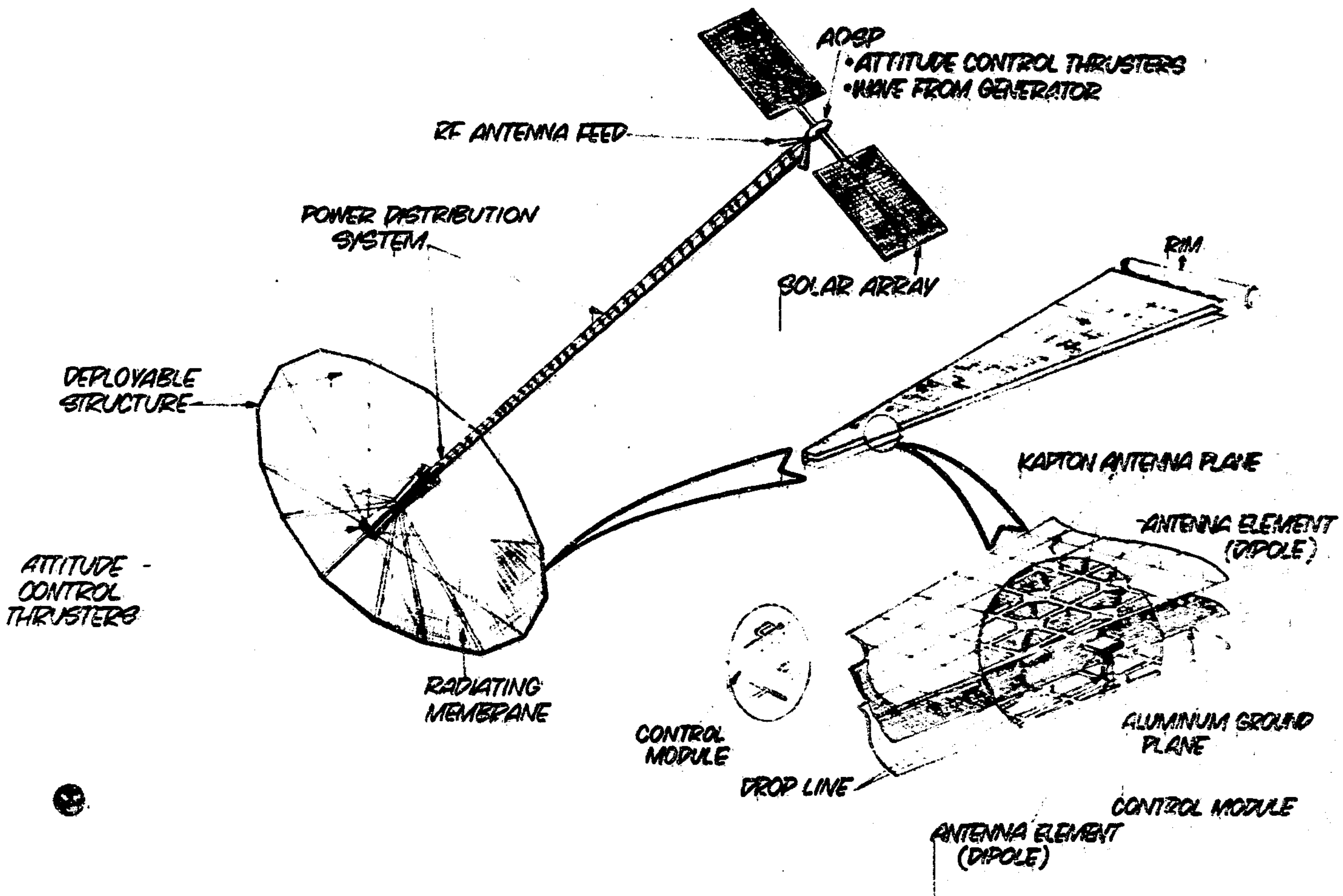

Figure 1. - Space-fed phased array-SBR antenna.

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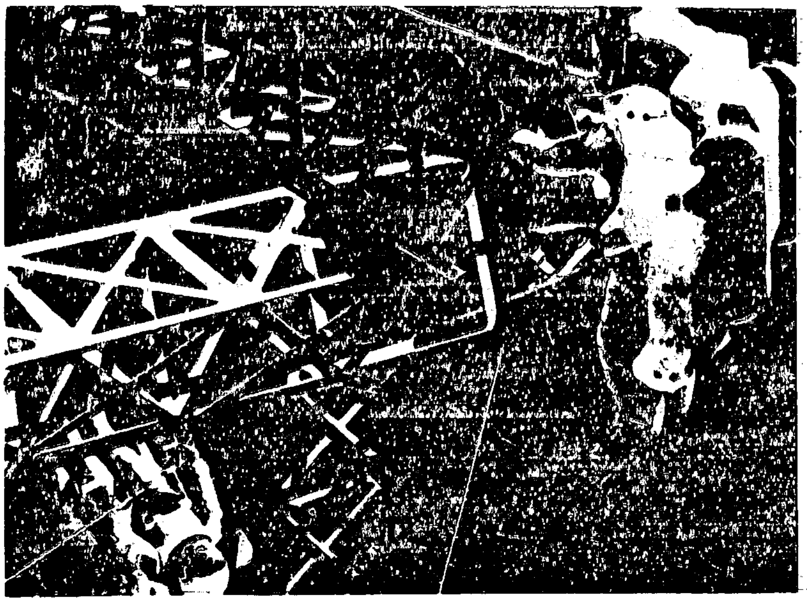

Figure 2. - Extravehicular activity in space.

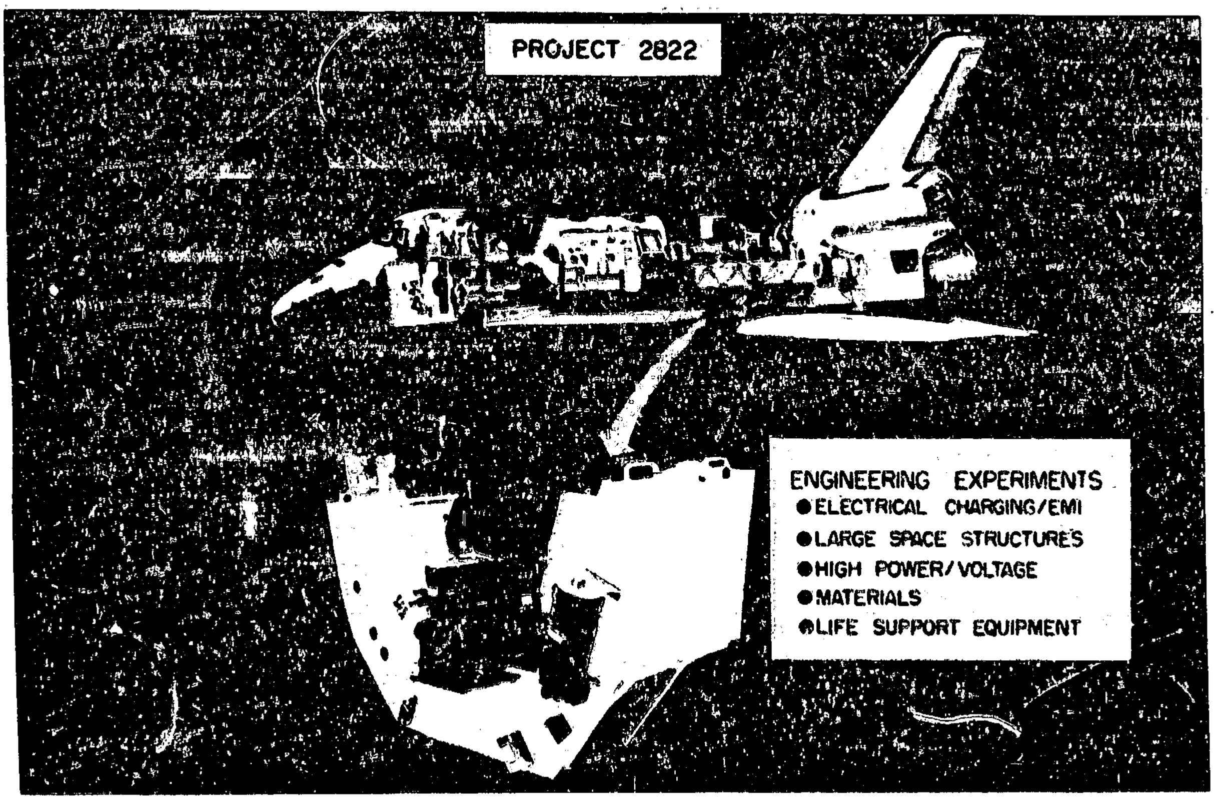

Figure 3. - Interactions measurement payload for Shuttle (IMPS).

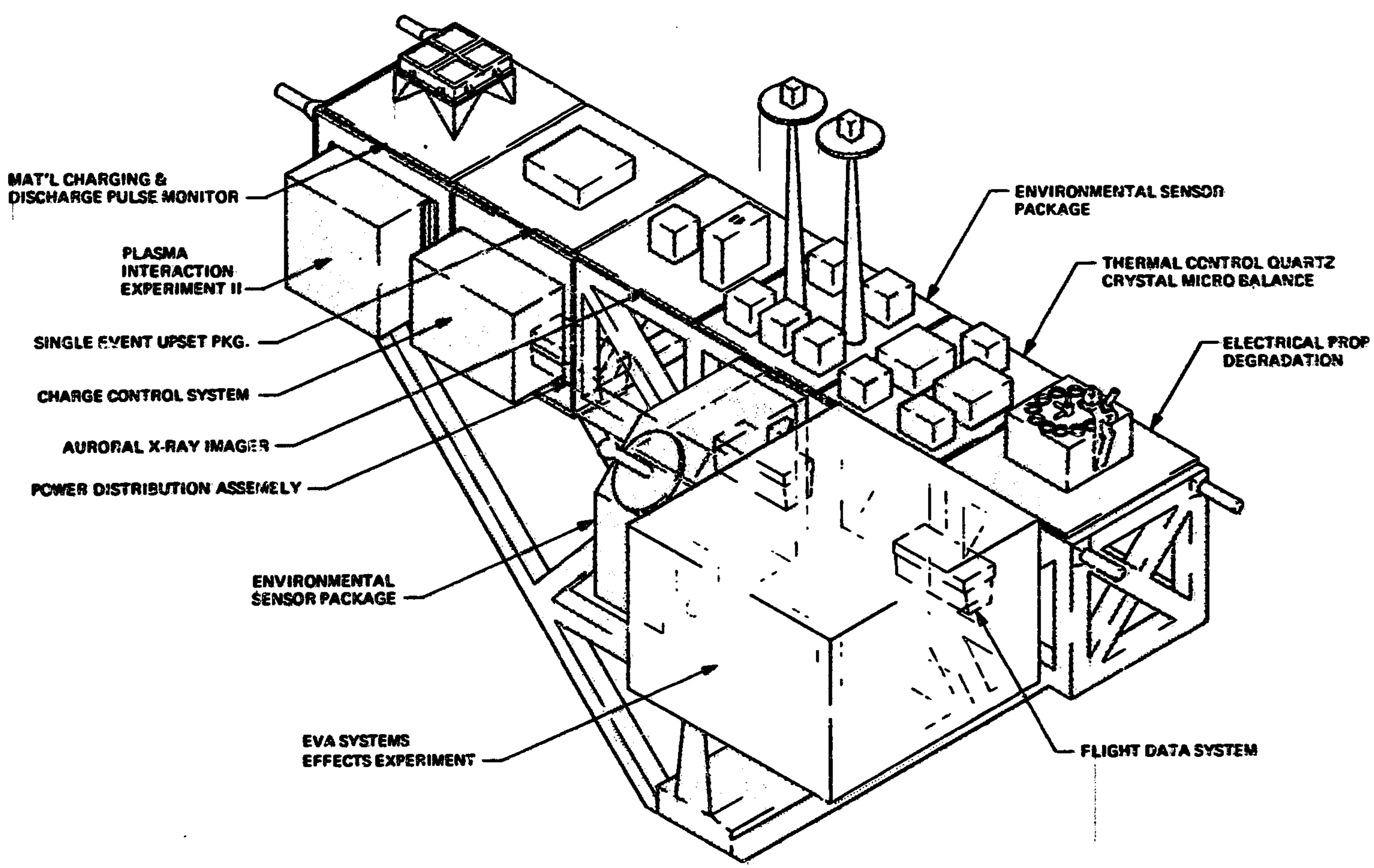

Figure 4. - IMPS payload, mod C.